(12) UK Patent Application (19) GB (11) 2 070 782 A

(21) Application No 8106020
(22) Date of filing 26 Feb 1981
(30) Priority data
(31) 3007463
(32) 28 Feb 1980
(33) Fed. Rep of Germany (DE)
(43) Application published
9 Sep 1981
(51) INT CL³
G01R 15/10
(52) Domestic classification
G1U BV13B
G3N 288A 2
(56) Documents cited
None
(58) Field of search
G1U
G3N
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(54) Apparatus for providing fuel metering control signals

(57) Apparatus for providing fuel metering control signals for a fuel feed system in an internal combustion engine comprises means (1) for providing non-linear air flow rate measuring signal values and a quasi-linearisation circuit arrangement (14a) or a non-linear voltage frequency converter for partially linearising these signal values. The resulting signal is integrated 15a and converted to a control signal t_p by means 12 responding to the unambiguous signal from the integrator. Such apparatus may enable avoidance of ambiguities due to high non-linearities in the air flow rate signal values and yet may be capable of economical mass production.

FIG. 1a

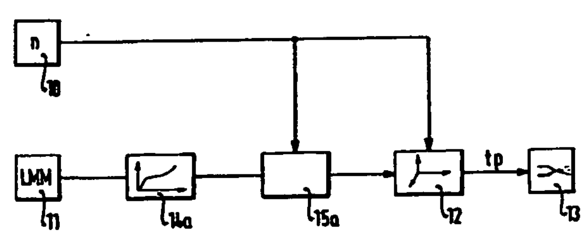

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FIG. 1a

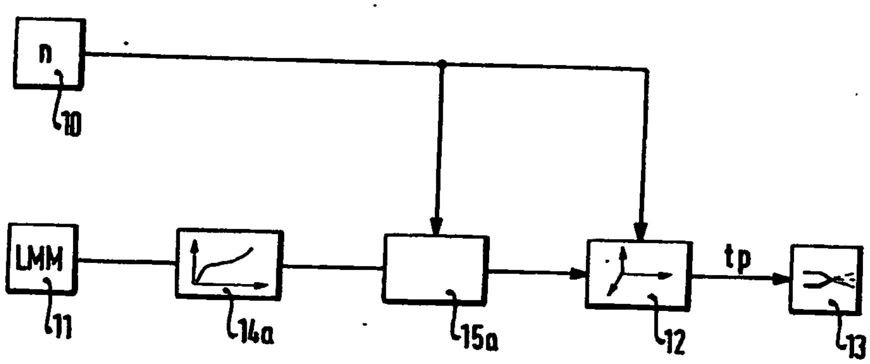


FIG. 1b

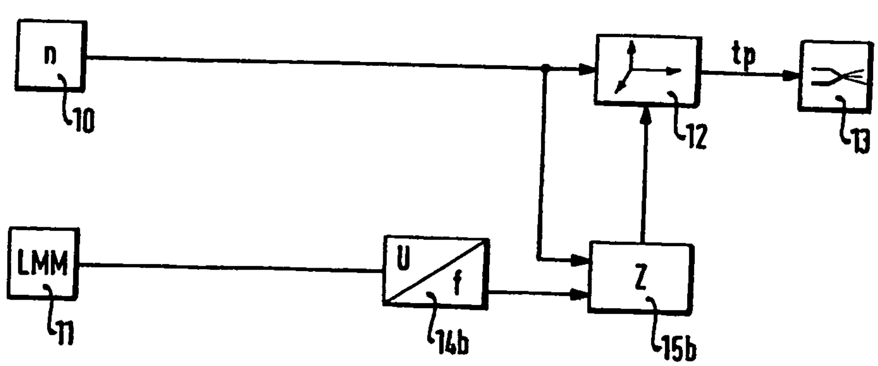


FIG. 2

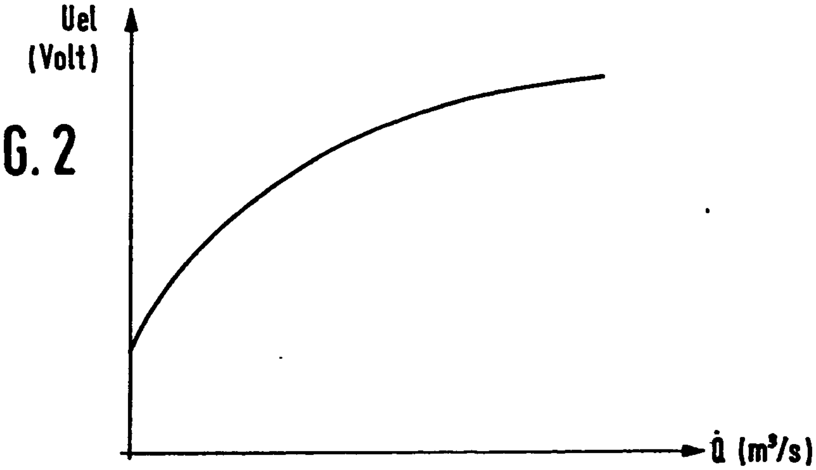


FIG. 4

a)

b)

c)

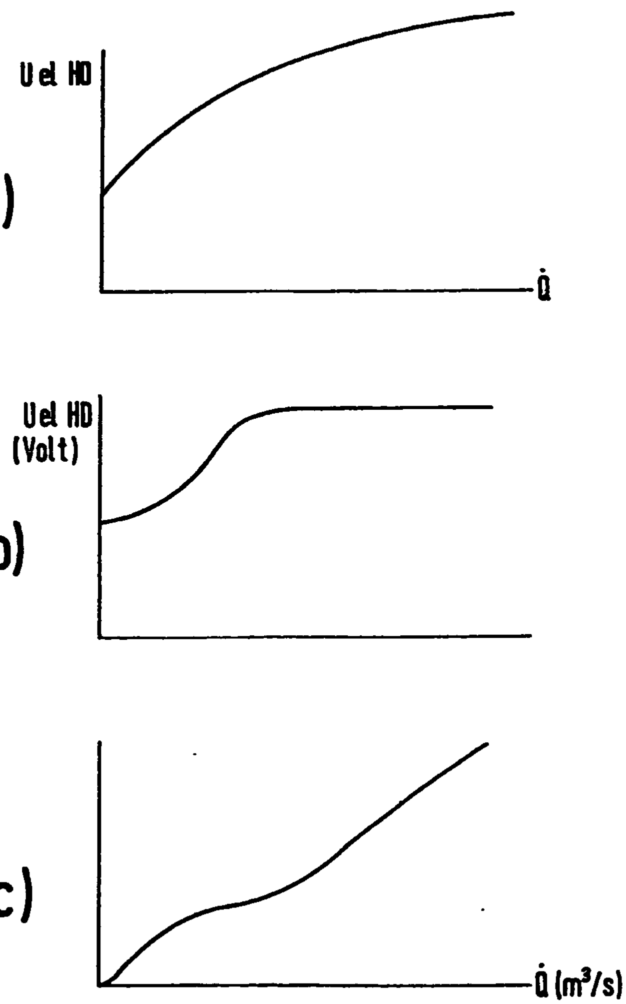


FIG. 3

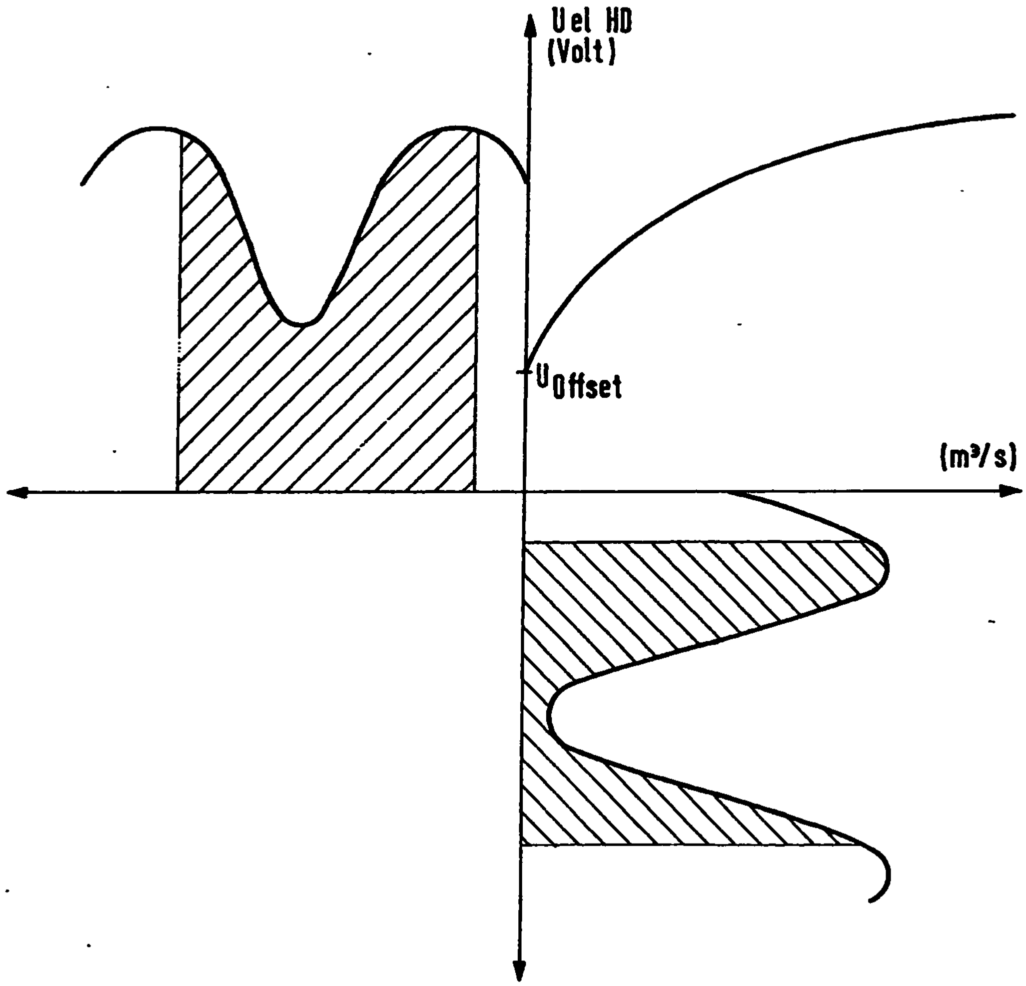


FIG. 5

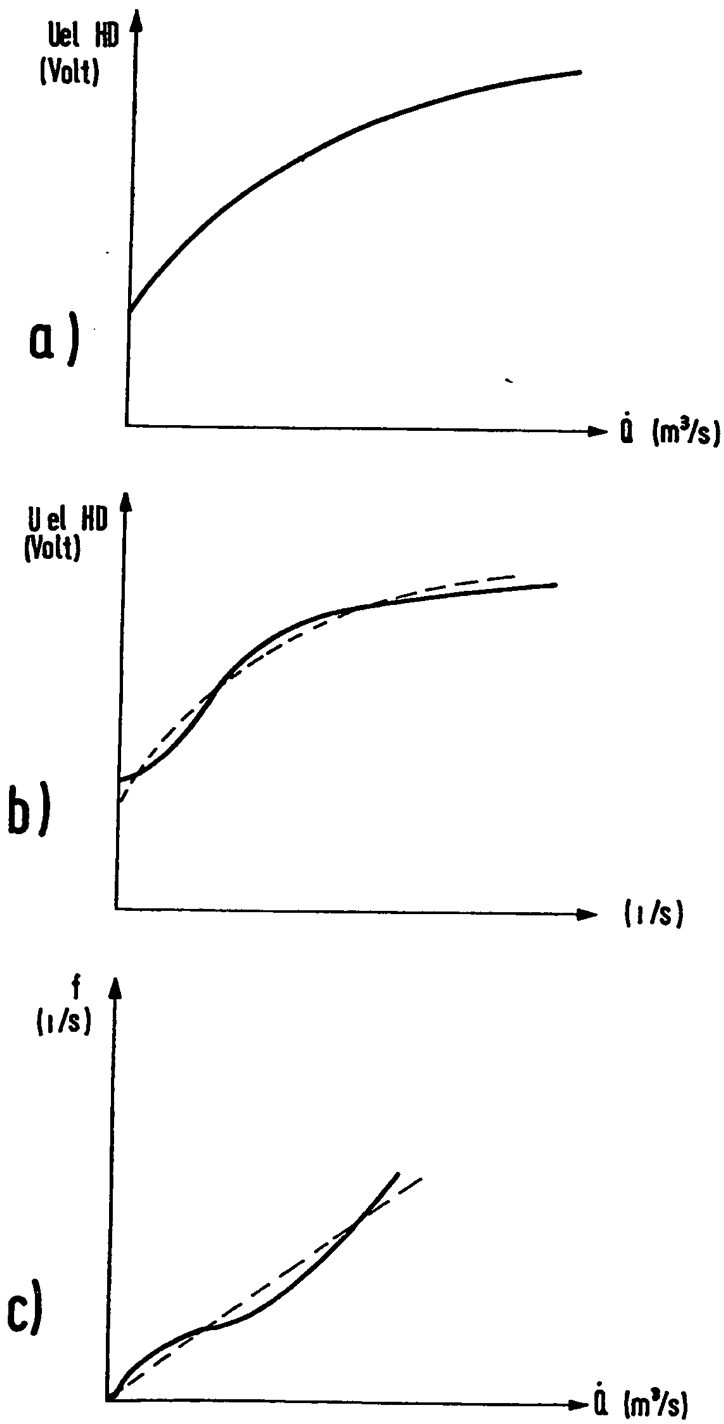


FIG. 6

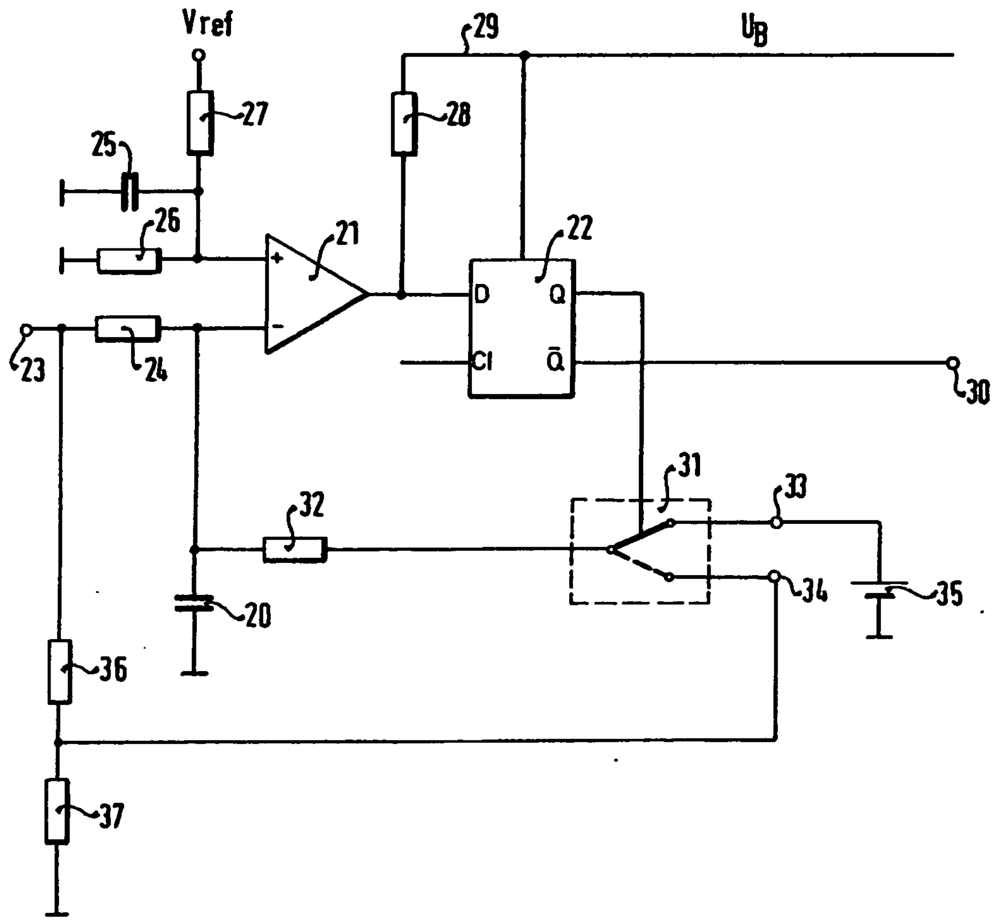
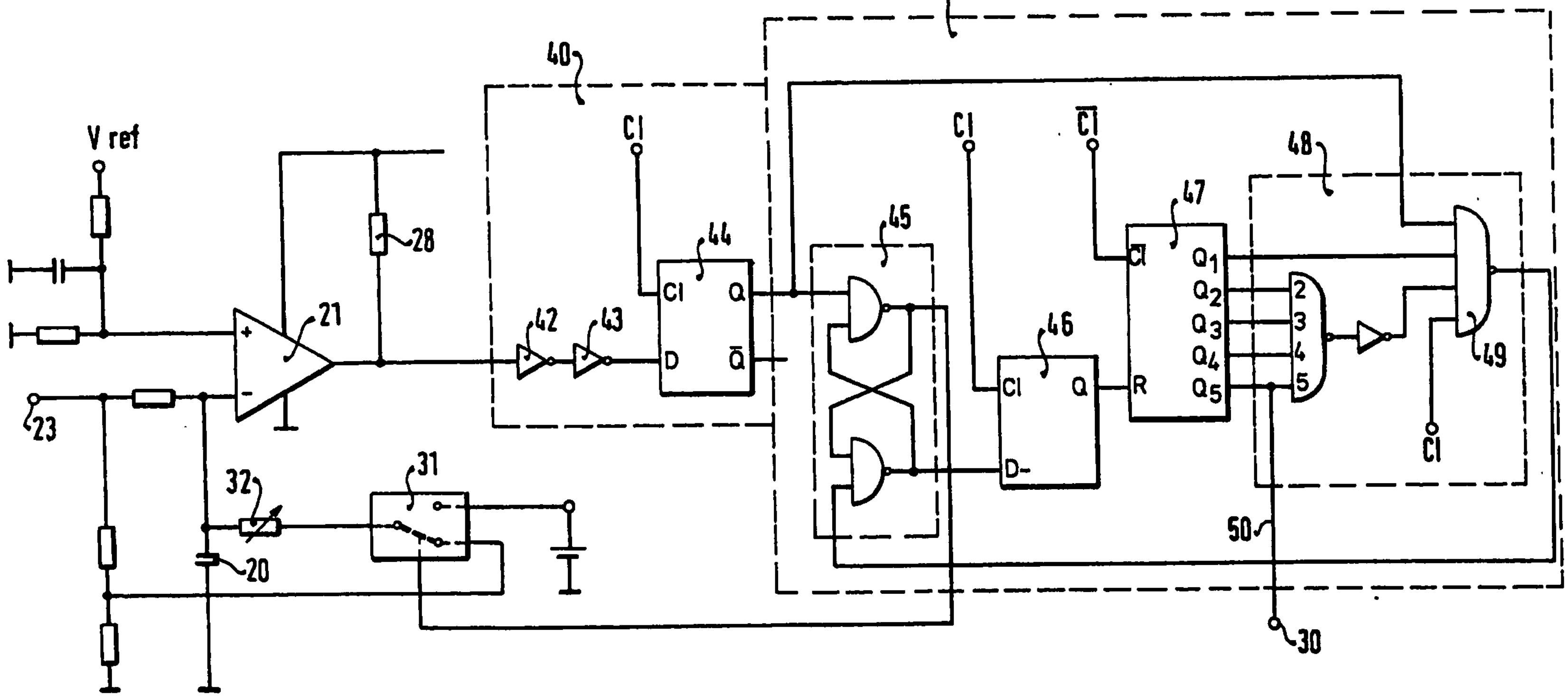


FIG. 7



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SPECIFICATION

Apparatus for providing fuel metering control signals

The present invention relates to apparatus for providing fuel metering control signals for a fuel feed system in an internal combustion engine.

The most important engine operational magnitudes to be processed in electronic control of a fuel metering installation are engine speed and engine load. For determining engine load, pressure sensors or air mass flow meters operating in conjunction wth a damper valve are commonly used. More recently, however, hot wire air mass flow meters have proved satisfactory, as they do not possess any mechanically moved parts and can make allowance for the induction air temperature in the measurements they perform.

To enable a desired combustion mixture to be metered as precisely as possible, it is necessary to determine the air mass inducted during each working cycle of the engine. Existing air mass flow meters, however, measure only the air throughput, i.e. air mass per unit time, so that the desired air mass per suction stroke has to be determined indirectly by integration of the air throughput with respect to time.

The air throughput per time unit is not constant over a working cycle, but exhibits a time-based wave form due to the various opening and closing movements of the individual inlet valves and resonance phenomena in the induction ducting. With a linear air mass measuring element providing an electrical measurement output signal proportional to the air throughput, this wave form does not present any difficulties, because the integral of the signal is also proportional to the integral of the air throughput (= air mass). Consequently, the integral can serve directly for controlling the timing element of an injection installation.

In general, however, the proportionality between the integrals of air throughput and electrical signal no longer exists with a non-linear air mass flow meter, such as for example the hot air mass flow meter. Problems now arise insofar as this non-proportionality cannot be corrected by a stored characteristic field, because the integral of the electrical signal f, which in turn is a function of the air flow g, thus of time t and specific engine operating states x_i (x_1 = load, x_2 = engine speed, etc.), is not unambiguous function of the operating states x_i. This integral therefore cannot be used for characterising the instantaneous engine operating state and for determining the quantity of fuel to be metered:

$$I\ (x_1, x_2, \ldots, x_i) = \int f\ [g\ (x_1, x_2, \ldots x_i, t)]\ dt$$

$\neq$ unambiguous function $(x_1, x_2, \ldots, x_i)$

It is desirable to modify the transfer function f (g) of the air mass flow meter so that the integral I of the modified signal f becomes an unambiguous function of the specific engine operating states (engine speed, load). The unambiguity of the integral value I is ensured if, as in known fuel metering systems, the air mass measuring signal is linearized as ideally as possible, so as to provide an accurate proportionality between air throughput and the linearised electrical signal.

A circuit for the most accurate possible linearisation is described in United States Patent Specification No. 4 043 196. In this circuit, a function generator is connected behind a hot wire air mass flow meter and serves to generate the function $(y/z)^n$, wherein the values z and n are adjustably defined.

In the context of large volume manufacture of fuel metering installations, the use of pure linearisation circuits has proved to be too complicated and too expensive. In addition, the problem arises of the exactness of the linearisation and in this connection the question of replacement of individual components without major balancing or adaptation measures.

There is accordingly a need for apparatus in which the transfer characteristic of air throughput detecting means is modified only to the extent necessary to ensure unambiguity of the integral measurement value.

According to the present invention there is provided apparatus for providing fuel metering control signals for a fuel feed system in an engine, the apparatus comprising measuring means for measuring the rate of flow of engine induction air and representing the measured rate by output signal values having a non-linear relationship to the flow rate, a signal value translating stage for approximating the output signal values towards a linear relationship to the flow rate, the translating stage comprising one of signal value distortion removing means and linearising means in series with one of an integrator and a counter, and a metering control signal generating stage comprising means for storing or determining metering control signal values and means for generating fuel metering control signals having values selected or determined at least partly in dependence on the translated output signal values.

In apparatus embodying the present invention, relatively simple and thus economical electronic circuits can be employed for generating the approximate or quasi-linearisation, provided that the corrected signal values are used for determining the quantity of fuel to be metered only after processing via a stored characteristic field.

Embodiments of the present invention will now be more particularly described by way of example and with reference to the accompanying drawings, in which:-

Figure 1a is a schematic block diagram of fuel metering signal generating apparatus according to one embodiment of the invention,

Figure 1b is a schematic block diagram of fuel metering singal generating apparatus according to another embdiment of the invention,

Figure 2 is a diagram showing the characteristic curve of a hot wire air mass flow meter in apparatus embodying the invention,

Figure 3 is a time graph of the air throughput at the meter and the associated, non-proportional time graph of the electrical output voltage of the meter, as well as the associated areas to be integrated,

Figure 4 is a series of diagrams showing the transfer characteristic of a quasi-linearisation circuit in the apparatus of Figure 1a,

Figure 5 is a series of diagrams showing the transfer characteristic of a quasi-linearisation circuit in the apparatus of Figure 1b,

Figure 6 is a circuit diagram of a non-linear voltage-frequency converter in one form of the apparatus of Figure 1b, and

Figure 7 is a circuit diagram of a non-linear voltage-frequency converter in another form of the apparatus of Figure 1b.

Referring now to the drawings, there is shown fuel metering control signal generating apparatus for fuel metering in a fuel injection installation. The embodiments of the invention do not concern an injection system as such, but primarily the preparation and processing of a signal value provided in analogue form. For this reason, the apparatus may also be used in the context of, for example, controlled carburettor or diesel injection installations.

Figures 1a and 1b are simple block diagrams each showing electrical components of an injection installation, including an engine speed meter 10 and air mass flow meter 11, the outputs of which are connected directly or indirectly to timing element 12 for forming injection pulses tp for an injection valve 13. Connected between the meter 11 and timing element 12 is a series circuit consisting of either a quasi-linearisation circuit arrangement 14a and an integrator 15a, or a non-linear voltage-frequency converter 14b (more or less linearising the non-linear hot wire output characteristic) and a counter 15b. The integration limits of the integrator 15a and the counting limits of the counter 15b are determined by signals from the engine speed meter 10.

In the circuits shown in Figures 1a and 1b, a value that can be unambiguously associated with the air mass flowing through the engine induction duct in each working cycle is determined in the integrator 15a and counter 15b, respectively, and, starting from the integrator or counter state final value and from the engine speed output signal, a corresponding injection value is read out from, for example, a three-dimensional characteristic field contained in the timing element 12. Correction stages, for example for an acceleration enrichment, can be provided if so desired in the connection between the timing element 12 and injection valve 13.

Figure 2 shows the characteristic of the hot wire air quantity meter 11, i.e. the output signal of the meter 11 plotted against the time-related air mass flow through the engine induction duct. The ideal case would be a straight line from the origin with a positive slope. This ideal case cannot, however, be achieved for numerous reasons, and instead a more or less parabolic load is obtained starting from a hot wire voltage value which is not equal to zero at an air throughput equal to zero.

Figure 3 shows the problem of correctly determining the air mass for a non-linear air mass flow meter. In the first quadrant of the coordinate system, the hot wire characteristic is plotted, while the second quadrant, in the clockwise direction, shows the actual air mass, the curve form of which has a wave pattern due to the various opening and closing movements of the individual inlet valves. Transfer of the measured air mass via the characteristic curve shown in the first quadrant gives the hot wire voltage illustrated in the fourth quadrant, which is distorted with respect to the curve pattern in the second quadrant. The shaded areas in the curves of the second and fourth quadrants indicate the relevant time integral of each curve.

For digital signal processing, it has proved appropriate to determine the air quantity via a time grid and to summate the corresponding voltage values multiplied by a time interval. Here again, the error due to non-linearity of the hot wire meter output becomes apparent.

Starting from the non-linearity of the output of the hot wire meter 11, ambiguities can arise at each integrated value, so that error can occur in further signal processing. This can be avoided by quasi-linearisation through the quasi-linearisation circuit arrangement 14a of Figure 1a or the non-linear voltage-frequency converter 14b of Figure 1b. In this connection, the degree of linearisation will be oriented according to the probability of occurrence of ambiguities in the integrator output signal. This is clarified by the diagrams of Figures 4 and 5, wherein Figure 4 shows the adapting of the transfer characteristic of the quasi-linearisation circuit arrangement 14a of Figure 1a to the characteristic of the hot wire air mass meter, and Figure 5 shows the adapting of the transfer characteristic of the quasi-linearisation circuit arrangement, i.e. non-linear voltage-frequency converter 14b, of Figure 1b to the characteristic of the air mass meter. In both Figure 4a and Figure 5a, the output signal from the air mass meter is plotted against the time-related air throughput in the induction duct. Figure 4b shows the characteristic of the quasi-linearisation circuit arrangement 14a, and Figure 4c the output voltage of this circuit arrangement plotted against the time-related air throughput.

Correspondingly, in Figure 5b the transfer characteristic of the non-linear voltage-frequency converter 14b is illustrated, and in Figure 5c the output signal of this converter 14b plotted against the time-related air throughput.

An example of the quasi-linearisation circuit 14a will be dispended with, because function generators for analogue signal levels are generally known and can be realised by, for example, diode-resistor networks. The detailed design and dimensioning in any case has to be oriented to the particular hot wire air mass meter employed and accordingly a blanket statement on the details of such a circuit arrangement cannot be made.

Two examples of non-linear voltage-frequency converters are shown in Figures 6 and 7.

The main components of the voltage-frequency converter illustrated in Figure 6 are a capacitor 20, a comparator stage 21 and a D flipflop 22. An input terminal 23 is connected via a resistor 24 to the minus input of the comparator stage 21 and to the capacitor 20, which is also connected to earth. The plus input of the comparator stage 21 is connected via a parallel circuit consisting of a capacitor 25 and a resistor 26 to earth and, in addition, via a resistor 27 to a reference voltage source Vref. The comparator stage 21 is connected at its output via a resistor 28 to a plus conductor 29 and simultaneously supplied an input signal for the flipflop 22. The $\overline{Q}$ output of the flipflop 22 is connected to an output terminal 30 of the voltage-frequency converter, and the Q output of the flipflop is connected so as to provide an output signal to control a two-way switch 31, by which signals from two connection points 33 and 34 can be selectively delivered via a resistor 32 to the capacitor 20. A signal from a reference voltage source 35 is delivered to the connection point 33. The connection point 34 is connected with the junction of two resistors 36 and 37, which together constitute a voltage divider between the input terminal 23 and earth.

An essential aspect of the voltage-frequency converter of Figure 6 is the charging and discharging of the capacitor 20 as a function of the output signal from the D flipflop 22 by means of two signal sources (35 and 36, 37) independently of the other voltage supply, whereby the non-linearity of the voltage-frequency converter is achieved by the non-constant voltage value at the input 34.

The method of functioning of the voltage-frequency converter illustrated in Figure 6 is that each switching of the comparator stage 21 causes a potential change at the output terminal 30 of the converter and, due to the charging and discharging of capacitor 20 controlled by the output signal, the frequency of the output signal is in a defined relationship to the analogue input signal.

In the converter of Figure 6, a fixed association exists between the change of the output potential of the comparator stage 21, the cycle frequency which controls the D flipflop 22, and the switching moments of the two-way switch 31. This fixed relationship does not appear to be appropriate when a continuous association between input signal and output signal is desired. In this case, replacement of the D flipflop 22 of Figure 6 by a monostable multivibrator with digitally quantized time bases appears advantageous. An example of this is illustrated in Figure 7.

The converter of Figure 7 has the same construction as that of Figure 6, except that the D flipflop 22 shown in Figure 6 has been replaced by a series circuit consisting of synchronising stage 40 and digitally operating monostable multivibrator 41. The synchronising stage 40 comprises two successively switched inverters (Schmitt triggers) 42 and 43, which are disposed in the connection from the output of the comparator stage 21 to the D-input of a D flipflop 44 in the synchronisation stage 40. At its output side, the flipflop 44 is connected to the monostable multivibrator, which consists of a series circuit of a bistable multivibrator 45, D flipflop 46, counter 47 and decoder device 48. The two outputs of the bistable multivibrator 45 are connected to the following flipflop 46 and to the control input of the two-way switch 31. The Q output of the flipflop 46 is connected to a resetting input of the counter 47. The decoder device 48 consists essentially of a NAND-gate 49, the output of which is connected to the second input of the bistable multivibrator 45. One of the inputs of the NAND-gate 49 is also connected to the first input of the bistable multivibrator 45, to which an output signal from the synchronising stage 40 is applied, as a result of which the decoder device 48 cannot conduct a resetting pulse to the second input of the bistable multivibrator 45 unless the comparator 21 or synchronisation stage 40 has previously switched over. Finally, a line 50 from the MSB connection of the counter 47 is connected to the output 30 of the converter.

An essential feature of the converter of Figure 7 is the monoflop provided by the counter and decoder device, the monoflop being able to supply a digitally quantised period of time in accordance with the cycle frequency. With this monostable multivibrator a pulse duration can be set, whereas the period duration of the output signal at the output 30 is dependent upon the signal at the input terminal 23.

The two above-described voltage-frequency converters have proved to be extremely favourable in conjunction with the circuit of Figure 1b. As a consequence of the only partial linearisation of the air mass signal and the residual correction via a characteristic field in the timing element 12, the transfer characteristic does not need to correspond to any a priori predetermined mathematical function, but only need be of a strictly repeatable nature, a feature which has proved advantageous in the context of economical mass production.

CLAIMS

1. Apparatus for providing fuel metering control signals for a fuel feed system in an engine, the apparatus comprising measuring means for measuring the rate of flow of engine induction air and representing the measured rate by output signal values having a non-linear relationship to the flow rate, a signal value translating stage for approximating the output signal values towards a linear relationship to the flow rate, the translating stage comprising one of signal value distortion removing means and linearising

means in series with one of an integrator and a counter, and a metering control signal generating stage comprising means for storing or determining metering control signal values and means for generating fuel metering control signals having values selected or determined at least partly in dependence on the translated output signal values.

2. Apparatus as claimed in claim 1, wherein the signal value translating stage is adapted to linearise the output signal values to an extent dependent on a predetermined probability of ambiguity or actual ambiguity in values of outputs of the integrator or counter based on the output signal values without said translation.

3. Apparatus as claimed in either claim 1 or claim 2, the measuring means comprising a hot wire or hot strip air flow meter.

4. Apparatus as claimed in any one of the preceding claims, the linearising means comprising a non-linear voltage-frequency converter.

5. Apparatus as claimed in claim 4, wherein the voltage-frequency converter comprises chargeable and dischargeable storage means, a comparison stage connected at an input thereof to an output of the storage means, and a trigger stage connected at an input thereof to an output of the comparison stage, the trigger stage being adapted to provide switching signals to determine charging and discharging states of the storage means.

6. Apparatus as claimed in claim 5, wherein the trigger stage comprises a monostable multivibrator with a time base quantised by counting and decoding means.

7. Apparatus as claimed in claim 5, wherein the storage means is dischargeable at a rate dependent on the signal from the measuring means received by the voltage-frequency converter.

8. Apparatus for providing fuel metering control signals for a fuel feed system in an engine, said apparatus being substantially as hereinbefore described with reference to Figures 1a, 2, 3, 4 and 6 of the accompanying drawings.

9. Apparatus for providing fuel metering controls signals for a fuel feed system in an engine, said apparatus being substantially as hereinbefore described with reference to Figures 1a, 2, 3, 4 and 7 of the accompanying drawings.

10. Apparatus for providing fuel metering control signals for a fuel feed system in an engine, said apparatus being substantially as hereinbefore described with reference to Figures 1b, 2, 3 and 5 of the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1981.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.